Saskatchewan Technology Enhancement Program

Summary Report

by

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Saskatchewan Research Council

and

H. Epp and D. Heyland
Canada Centre for Remote Sensing

SRC Technical Report No. 213
February, 1988

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SASKATCHEWAN TECHNOLOGY ENHANCEMENT PROGRAM FOR REMOTE SENSING SUMMARY REPORT

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ABSTRACT

Over a two year period SRC, in collaboration with CCRS, developed a remote sensing centre to introduce and demonstrate this technology to potential users within Saskatchewan. The organizational process was inaugurated via a memorandum of understanding between the two governments, establishing the Saskatchewan Technology Enhancement Program (STEP) within which the remote sensing activities took place.

Nine demonstration projects were initiated in consultation with interested federal and provincial departments and agencies. Each was designed to demonstrate the capability of remote sensing technology to address a specific problem of interest to that organization. Each project had as its objective, to determine whether remote sensing techniques could be utilized operationally to provide a more comprehensive, more timely or less costly answer than that obtainable from previously used approaches.

This report provides an outline of STEP, and presents brief summaries of the nine projects. Each of the latter is the subject of a more comprehensive report that is referred to herein, and is separately obtainable.

ACKNOWLEDGMENTS

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GLOSSARY

Bands and Channels. The sensors in a multi spectral scanner record a scene in a number of different narrow wave length windows. These windows are called bands or channels.

Channels. See bands and channels.

Contrast Stretching. Raw Landsat data typically occupy only half of the possible reflectance range. For example, one band for an image may have reflectance values ranging from 10 to 100 out of a possible extent of 0 to 255. By applying a contrast stretch, the contrast of an image is maximized, thereby enhancing the visual and digital interpretation capabilities.

Enhancements. Any of several photographic or computer aided processes used to enhance an image for improved interpretation. Enhancements include contrast stretching, filtering, two band manipulations and multi data combinations.

Histogram Equalization. A histogram equalization is a type of contrast stretch where the reflectance values for an image are redistributed such that approximately an equal number of pixels are set to each reflectance value.

Image. A photographic-like representation of an object generally acquired through electro-optical or electronic means as opposed to a photographic system using film.

Landsat. A series of sun-synchronous earth resource satellites that carry a multi spectral scanner (MSS). The more recent Landsat satellites also carry a high-resolution multi band sensor (TM). The data are returned to earth as electronic signals, recorded on magnetic tape and as photographic images for computer and optical analysis.

Linear Stretch. A linear stretch is a type of contrast stretch where the range of reflectance values for an image is redistributed over the entire extent of possible values. A minimum limit (cutoff point) and maximum limit (saturation point) are chosen for the band. Values less than the cutoff point are set to the minimum value and values greater than the saturation point are set to the maximum value.

Logarithmic Transformation. A log transform is a type of contrast stretch where the reflectance values for an image are redistributed so they fit a normal distribution.

MSS, Multi Spectral Scanner. A scanner that simultaneously records ground reflectance data for four wave length ranges (bands).

Parallelepiped Classification. A classifier which, after being trained upon a certain area, identifies the maximum and minimum digital values in each of two to four spectral bands to define the spectral boundaries of the class. Each pixel in the image is then compared to that class parallelepiped thus defined to determine if it falls within its bounds. This procedure, may be repeated for any number of classes.

Piece-wise Linear Stretch. A piece-wise linear stretch is a type of contrast stretch which is similar to a linear stretch. However, a piecewise linear stretch allows the amount of stretching to vary over the range of reflectances for an image.

Pixel. In an image, the data are stored in a grid-like format. Each individual grid cell is referred to as a picture element, or pixel for short.

Remote Sensing. The art and science of detection, identification and evaluation of objects while not coming into direct contact with them. Normally this term is used in context with aircraft or satellite imagery.

them. Normally this term is used in context with aircraft or satellite imagery.

Supervised Classification. In a supervised classification, the analyst identifies areas in the image with a known ground cover. The computer then searches the entire image for areas with similar ground reflectances or decision rules and identifies them as of one group.

Task. Each step in the image analysis process may require the execution of one or more computer programs. These programs are frequently identified as tasks.

TM, Thematic Mapper. A high-resolution multi spectral scanner sensor which records ground reflectance data for seven wave length ranges (channels) that are narrower than for MSS.

Unsupervised Classification. In an unsupervised classification, the computer scans the entire image and identifies natural groupings or clusters in the ground reflectance values. Classification groupings are usually based on vegetation patterns but may also be affected by soil moisture, slope, aspect, etc. The spectral clusters are identified by comparing their spectral patterns with geographic information about the cover types in the area.

1. INTRODUCTION

Remote sensing from space is not a new technology. For over 15 years, the American Landsat series of satellites has been orbiting the earth, scanning and monitoring the resources of the world. The American NOAA series of weather satellites complements Landsat. Most recently, they have been joined by the French SPOT satellite, the newest generation of operational remote sensing platforms. The European Space Agency and Japan have launched additional remote sensing satellites and Canada may soon have its own satellite, Radarsat, adding the new capability of microwave observation. Truly, the world has recognized the need for remote sensing.

Canada has been committed to, and is extremely active in, the space program from its very beginnings. For over 15 years, the Prince Albert Satellite Station (PASS), operated in Saskatchewan under contract by SED Systems Ltd, has been collecting satellite remote sensing data on Canada. During that time, the Canadian remote sensing business has been growing at 30% per year with sales of $120 million in 1985 by 64 Canadian companies employing some 1400 people. Over half of these sales were exported as services and as equipment and software for reception and data processing. The total world market for 1985 was estimated to be $1 billion (US) of which 8% was Canada's share.

There have been numerous studies which demonstrate the benefits of using remote sensing in real dollar terms. One example is the Large Area Crop Inventory Experiment (LACIE) in the United States which demonstrated the accurate and timely monitoring of wheat production in the USSR. The LACIE program generated estimated benefits exceeding $200 million (US) per year. In Canada, a project of this type would generate benefits exceeding $100 million per year. In another example, over $350 million worth of gypsum was discovered based upon Landsat digital imagery analyzed on a Canadian system. The world's largest coal mine was recently discovered in China using remote sensing on a Canadian made remote sensing system.

1.1 Objectives

The objectives of the Saskatchewan Technology Enhancement Program (STEP) were:

1. To train Saskatchewan resource managers and government personnel in the uses of remotely sensed data.
2. To provide a facility, equipment and a remote sensing specialist to support the Program.
3. To provide a forum for exchange of information.

1.2 The Need

Saskatchewan's diverse resources (natural, cultivated and non-renewable) are the core of the Saskatchewan economy. Of the $5.4 billion worth of products and services exported from Saskatchewan in 1984, nearly 80% were directly related to three main resource industries: $2.3 billion in minerals, $1.75 billion in agricultural goods, and $231 million in forest products. The long-term stability of Saskatchewan's economy and the continued well-being of Saskatchewan's citizens are highly dependent upon the effective management of these resources to ensure abundant and continuing supply, efficient use, and profitable and competitive production for world markets.

Potential users of remote sensing in Saskatchewan have taken advantage of an opportunity to test the technology against their requirements. The Saskatchewan Technology Enhancement Program (STEP) was the result of

a Memorandum of Understanding (MOU) between the Canada Centre for Remote Sensing (CCRS) and the Saskatchewan Research Council (SRC) signed in January 1985. STEP started with seven operational demonstration projects. Three additional projects came later. The program was completed in March 1987, although an equipment extension has been received.

As its contributions to the success of the STEP, CCRS stationed a remote sensing specialist, Helmut Epp, at SRC for the duration of the Program. In additon CCRS loaned a digital image analysis system to SRC on which data analyses for the STEP projects were performed.

The window of opportunity opened by STEP has provided SRC with a view of the obligation required to continue providing assistance to these users as they attempt to move into operational use and reap the on-going benefits. Choosing not to continue, or being restricted from improving the service when the STEP system moves to its next committed site, would have denied the first Saskatchewan users access to a technology available to their counterparts elsewhere in Canada. The potential benefits afforded by remote sensing would have been lost to them and to the economy and the people of the province as a whole.

2. EVALUATION OF THE STEP PROGRAM

This section provides an introduction to the STEP demonstration projects: the study areas, their objectives, results and recommendations. In addition to the designated STEP projects, several other projects were completed and are described at the end of this section.

2.1 The Demonstration Projects

The STEP program had ten demonstration projects which included migratory waterfowl, deer, moose and caribou habitat; bulk area estimates of crops; field boundary assessment; forest fuel mapping; burn and cut-over inventory; salinity in irrigated areas; and depression storage as a measure of flood potential. The migratory waterfowl project started very late and will not be completed during STEP, hence no report is included here.

The projects were well distributed over the province (Figure 1). The principal investigators also came from various parts of the province. There was a variety of digital and visual analysis techniques used in executing the projects with the image dates, type of digital data, auxiliary data collected, and the classification method shown in Table 1. The degree of success, for each technique, is also indicated.

2.2 Results and Recommendations

2.2.1 Field Measurements Using Thematic Mapper Data in the Swift Current Area of Saskatchewan (by S. F. Benjamin, Saskatchewan Crop Insurance Corporation, Melville).

Objectives

1. To determine the feasibility and cost effectiveness of using satellite data to measure field sizes.
2. To determine the difference between

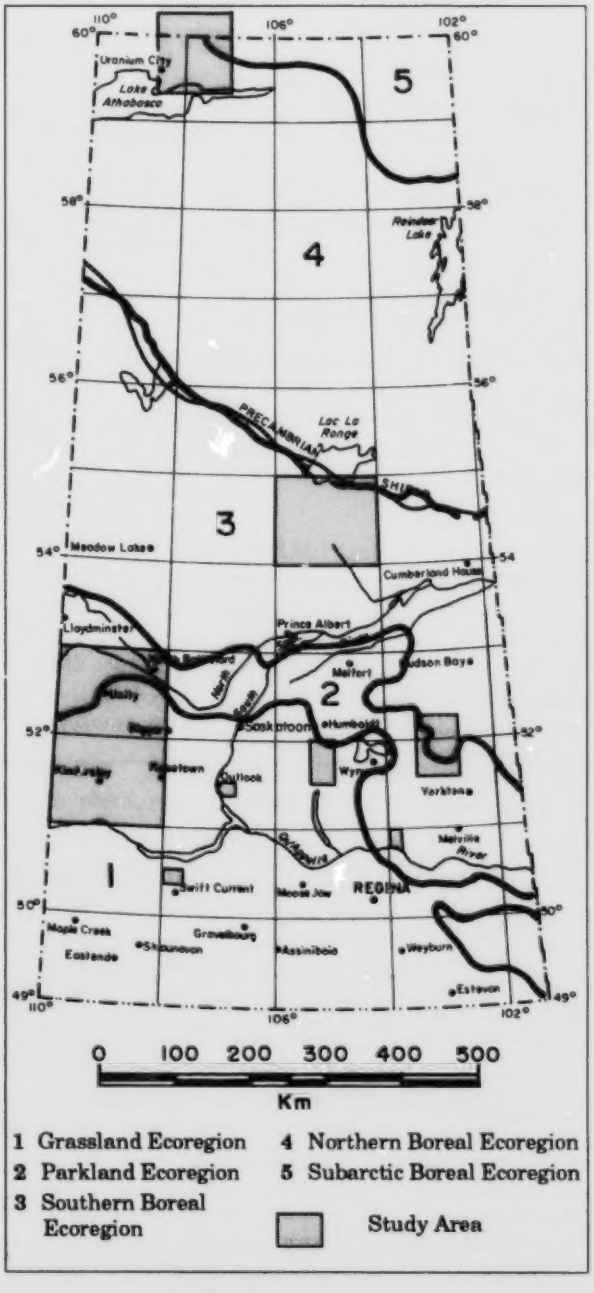

Figure 1. STEP Study Areas.

TABLE 1.
DEMONSTRATION PROJECT DATA COLLECTION AND ANALYSIS ASSESSMENT,
Saskatchewan Technology Enhancement Program

	Project	Image Date	MSS	TM	Data Ground	Collected Aerial	Classification Method			
							DP	IT	UC	CU
2.2.1	Field Boundaries	20/07/84	x	x	1984		+	+	-	x
2.2.2	Forest Cover									
	Burns	10/06/84	x			1983-5	+	+	-	
	Clearcuts	08/10/84	x		1984	1983-5	+			
	Roads	10/06/84	x		1984	1983-5	+			
2.2.3	Caribou Habitat		x		1984		+	+	-	x
2.2.4	Crop Area	06/08/85	x		1985		+	+		x
		05/07/85	x		1985			+		x
2.2.5	Deer Habitat	03/06/84	x		1981+5	1970		+	-	
2.2.6	Forest Fire Fuel	06/06/84	x		1984	1986	+	+	-	x
2.2.7	Moose Habitat	06/06/84	x		1984	1986	+	+	+	x
		08/10/84	x		1984	1986	+	+	-	x
2.2.8	Salinity in Irrigated Fields	11/07/84		x	1986	1986	+	+		
2.2.9	Drained Land	15/05/79	x		1984-6		+	+		
		29/08/83								
		04/06/84								
		07/06/85								
		16/08/85								
		29/10/85								

note: DP - fast parallelepiped classifier
IT - interactive training area choice with maximum likelihood classifier
UC - unsupervised spectral signature generation with maximum likelihood classifier
CU - post classification filter

x - choice of use
\+ - best/acceptable method
\- - poor choice

spring seeded crops and fall seeded crops as well as between improved grassland and native grassland.

Study Area The study was undertaken in two areas: (a) Swift Current and (b) the Qu'Appelle Lakes area - each involved approximately 12 km^2.

Results

1. The field boundaries of the large square and rectangular fields in the Swift Current area were determined to an accuracy of 82%. The cost of providing this information was $9,000.

2. Crop types in the two Swift Current areas were determined to an accuracy of over 95 and 90%, respectively. The smaller fields in the Qu'Appelle Lakes area, were identified at a level below 80% accuracy.

Recommendations

1. Remotely sensed data should be used as part of the short and long term planning and data gathering requirements for the following data types: field boundaries, crop types, crop conditions, maps of areas affected by drought, areas affected by severe weather and vegetation types. 2.

   A regression estimator should be used as well as more detailed analysis of Thematic Mapper (TM) data for field boundary delineation.

3. An operations centre should be set up in which image analysis can be done on a contract basis or users can book time to undertake projects.

2.2.2 Mapping of Recent Cutover/Burnover Areas Using Multi-Date Landsat Digital Imagery (by D.K. Ens, Forest Inventory Branch, Saskatchewan Parks, Recreation and Culture (previously Saskatchewan Parks and Renewable Resources)).

Objectives

1. To map recent clearcut and burnover areas within the Wapawekka Hills area.
2. To up-date roads used in logging operations.

Study Area The Study site was in the Wapawekka Hill map area, east central Saskatchewan, covering an area of 14,244 km^2.

Results

1. Clearcuts and burns were mapped at an average accuracy level of 82% and 93%, respectively. The benefit/cost was calculated to be 5:1 over current ground and aerial photo interpretation.
2. Up-dating of roads was done with an accuracy of 73%.

Recommendations

1. Landsat data within the same year as the forest fires should be obtained to accurately assess burns.
2. TM data with its higher resolution should be used to provide more precise and accurate clearcut boundary definition.
3. The old NTS 1:50,000 maps should not be used as a geo-reference base for either the Forest Inventory Maps nor for the satellite classification assessment because of inaccuracies.
4. The use of multi-date Landsat data should be investigated for mapping partial cutovers.

2.2.3 Preliminary Forest Cover Mapping for Caribou Habitat (by J. Polson, Saskatchewan Research Council, Saskatoon and M. Campbell, Forest Fire Management Branch, Saskatchewan Parks, Recreation and Culture, Prince Albert).

Objective

1. To produce a preliminary forest cover type classification of the area lying northwest of Beaver Lodge Lake.

Study Area The study area was in Uranium City/Stoney Rapids area of Northern Saskatchewan covering an area of 386,856 ha.

Results A thematic map and area calculations of 6 forest cover classes was produced at a scale of 1:250,000 scale.

Recommendations Although no follow-on project has been planned, it is recommended that the procedure used in this project be used in areas where little or no ground data have been collected or will be collected in the future. It is further recommended, that the Saskatchewan Park, Recreation and Culture should undertake such a study for the whole Saskatchewan Caribou range in order to assist in develop mining and recreation planning guidelines for the area.

2.2.4 Crop and Summerfallow Area Estimation in Saskatchewan Using Landsat MSS Data for 1985 by (R. Dobbins, Statistics

Canada, Ottawa and H. Epp, Canada Centre for Remote Sensing, Saskatoon).

Objectives

1. To demonstrate the effectiveness of Landsat MSS data for estimating crop area statistics and land cover data in Saskatchewan.
2. To provide acceptable area estimates for total cereal grains, canola/rapeseed and summerfallow in crop districts 7a and b.
3. To provide an evaluation of the cost effectiveness of using satellite data for crop area estimations.

Study Area The study area was Crop Districts 7 a and 7 b located in west central Saskatchewan.

Results

1. Crop area statistics and land cover data were estimated for Crop Districts 7 a and 7 b.
2. Tables of cereal grains, canola/rapeseed and summerfallow were produced and published in the 'September Forecast of Production of Principal Field Crops, Canada'. A regression estimator was used to improve the accuracy of the data provided by Stats. Canada and published in the 'November Estimate of Production of Principal Field Crops, Canada'. An accuracy level of 108% was obtained.
3. No evaluation of the economic and cost effectiveness of using satellites for crop area estimation was provided.

Recommendations

1. All efforts be made to control increasing costs of purchasing MSS digital data so that these types of programs remain operationally viable.
2. Pool research, resources and expertise to reduce costs.
3. Any follow-on projects using satellite data must be based on a sound statistical framework and estimation procedure.

2.2.5 Updating of the Wynyard (72P) Landuse Map Using Landsat Digital Data (by P. Bealieu, Saskatchewan Parks and Renewable Resources (now Saskatchewan Parks, Recreation and Culture)).

Objectives

1. To update the Terrestrial Wildlife Habitat Inventory (TWHI) landuse map of the Wynyard area at 1:250,000 scale.
2. To sub-divide the native vegetation classes into native pasture, shrubland, and wooded cover.
3. To prepare a colour map of vegetation classes.
4. To calculate the area of each cover class.

Study Area The Wynyard Map area (72P) was reduced to one Wildlife Management Zone (# 22) with an area of 3200 km^2.

Results

1. An updated version of the TWHI for Wildlife Management Zone (# 22) was produced at the scale of 1:250,000.
2. The native vegetation was sub-divided into grassland and tree cover because it was not possible to differentiate between tree and shrub cover. The benefit/cost was calculated to be 4:1 over the current method of airphoto interpretation.
3. The area of each cover class was calculated with an overall accuracy of 93%.

Recommendations

1. The landuse maps produced from satellite data replace the TWHI maps currently in use.
2. The simple overlay method of a satellite colour transparency and verification of the current condition of the native vegetation be investigated.
3. A computer operator should work with the principal investigator to eliminate the learning time required for the principal investigator.
4. The Wildlife Branch should review its ob-

jectives and determine if a replacement through the use of satellite data is required or merely to revise the rate of habitat loss.

5. If a replacement of the TWHI map is required, the pilot project, (with modifications and more staff) should be implemented.

2.2.6 Forest Fuel Classification Using Landsat MSS Digital Data (by M.E. Campbell, Forest Fire Management Branch, Saskatchewan Parks, Recreation and Culture, Prince Albert).

Objectives

1. To assess the feasibility of using Landsat MSS data to map forest fuel types for the Wapawekka Hills area.
2. To create a thematic map at 1:250,000 scale.
3. To compare the thematic map data to the existing forest cover map.

Study Area Wapawekka Hill map area is located in east central Saskatchewan covering an area of 14,000 km^2.

Results

1. The forest fuel cover types were classified into 12 categories.
2. A thematic map at 1:250,000 scale was created. Area calculations were generated in percent of total map area and also for each cover type. The benefit/cost was calculated to be 400:1 over current photogrammetric methods.
3. A mean accuracy level of 87% was obtained compared to forest inventory maps.

Recommendation Production of maps derived from satellite data should be integrated into the normal operating procedures of fire managers.

2.2.7 Cover Type Mapping in the Commercial Forest Region of Saskatchewan for Moose Habitat (by J. Polson, Saskatchewan Research Council, Saskatoon).

Objectives

1. To assess the feasibility of using Landsat MSS data to map major vegetation types in the Wapawekka Hills area as an aid in moose population studies.2. To create thematic maps at scales of 1:250,000 and 1:125,000
3. To compare the thematic map data to existing forest cover maps

Study Area Wapawekka Hill map area, in east central Saskatchewan, covering an area of 14,244 km^2.

Results

1. The natural cover types and those influenced by man were classified into 12 categories.
2. Thematic maps at 1:125,000 and 1:250,000 scales were created. Area calculations were generated in percent of total map area and also for each cover type.
3. A median accuracy level of 83% was obtained when comparing the data to forest inventory maps.

Recommendation Saskatchewan Parks, Recreation & Culture (Wildlife Branch) should adopt this method for classifying ungulate habitat and possibly the habitats of other species.

2.2.8 Salinity Area Identification and Mapping Within the South Saskatchewan River Irrigation District #1 (by B. King, Saskatchewan Water Corporation (previously Saskatchewan Agriculture), Outlook).

Objectives

1. To identify and map the area of reduced crop production due to high salinity levels on irrigated land.2. To investigate the potential uses of remotely sensed data to assist in determining irrigated agricultural production and the development of irrigation policy.

Study Area The South Saskatchewan River

River Irrigation District #1 near Outlook covers 20,000 ha.

Results

1. The analysis was not able to identify the reduced crop production due to high salinity levels on irrigated land at a suitable accuracy level. The digital data were accurate to between 20 to 30%. Visual interpretation of enhanced satellite images gave an accuracy similar to low level aerial photography but covered a much larger area for less cost.
2. The analysis of satellite data was able to provide irrigated agricultural production area estimates to over 90% accuracy. The capability to provide data for irrigation policy development was more successful.

Recommendation Area estimations of irrigated land for irrigated land policy development should be conducted for all of agricultural Saskatchewan.

2.2.9 The Determination of Depression Storage and Artificially Drained Area in the Assiniboine Basin, Saskatchewan Using Satellite Data (by B. Kallenbach, Saskatchewan Water Corporation, Moose Jaw).

Objectives

1. To determine the amount of depression storage present in the Assiniboine Basin.
2. To determine the location of, and provide area calculations for, artificially drained land.

Study Area The Assiniboine Basin centred on the town of Canora in east central Saskatchewan.

Results

1. Depression storage parameters were determined using satellite data although the format of the results and time frame of available data could not be readily transformed into usable information. Areas were classified and tabulated areas for four depression storage features: deep water, shallow water, marsh, and transition zone from marsh to wet field. An accuracy assessment was not performed since aerial photography was not available for the dates corresponding to the satellite images.
2. The extent of artificially drained land cannot be determined to an acceptable level of accuracy using satellite data. No accuracy assessment was done as no acceptable results were obtained.

Recommendations

1. Until there are some advances in analysis techniques and/or higher resolution in satellite data, depression storage parameters and mapping of artificially drained land should be done by conventional methods.
2. Any new types of satellite data should be evaluated for their usefulness in determining depression storage parameters and identification of artificially drained land.

2.3 Benefits From the STEP Program

2.3.1 Benefits From the Demonstration Projects

Space-borne data of the earth's resources can be applied to many problems facing resource managers, but do not hold the answers to all problems. Existing techniques such as air photo interpretation for example, are still the best in many areas (eg. detailed urban planning). However, when a resource manager must address a problem which involves an extensive area, or perhaps one in a remote and inaccessible region, he must turn to other data sources at low cost. Such criteria dictate space-borne data and to Saskatchewan resource managers this means Landsat. However, new data sources will not provide all the answers, but only another data source to be exploited.

Adopting a new technology is not without cost. Some are monetary, but many are related to human behaviour and attitude. Because the electronic equipment for manipulating Landsat data was available at low cost to Saskatchewan during STEP it need not be considered further.

TABLE 2.
ASSESSMENTS OF BENEFITS FROM DEMONSTRATION PROJECTS

	Project	Accuracy Assessment [%]	Benefit Cost Ratio	Time (hours) Training	System	Field	Program Cost Production [$]
2.2.1	Field Boundaries	82	n.d.	176	18	--	8,900
2.2.2	Forest Cover						
	Burns	93	5:1	255	12	70	10,550
	Clearcuts	82	5:1				
	Roads	73					
2.2.3	Caribou Habitat	n.d.	n.d.b.	0	20	20	--
2.2.4	Crop Area	108	n.d.	--	--	--	--
2.2.5	Deer Habitat	93	4:1	48	63	60	1,858
2.2.6	Forest Fire Fuel	87	400:1	100	72	20	4,170
2.2.7	Moose Habitat	87	35:1	200	40	20	2,200
2.2.8	Salinity in Irrigated Fields	90	n.d	200	40	n.d	--
2.2.9	Drained Land	-	n.d.	162	--	--	--

note: n.d. - not done
n.d.b. - not done before by any other method
-- - not available

Rather, challenges faced by the principal investigators will be considered.

All the principal investigators, as well as others, received basic training in remote sensing and digital image analysis. To most it was a new technology and to some, rather intimidating, resulting in a relatively long learning curve, particularly in the use of the image analysis system. Some investigators became very proficient in using the computer, while others experienced considerable difficulty. Still others, due to personal schedules or schedules imposed upon them, had long lapses between computer sessions and therefore were forced to relearn some procedures several times over. This became very frustrating in some cases.

As is always the case with satellite data, obtaining cloud-free imagery within a suitable "biological window" was a challenge. However, once obtained it was difficult in some of the studies to discriminate decisively between different types of ground cover. For example, trees versus shrub communities, spring crops and woody cover, cloud shadow versus similar dark areas on the landscape and jack pine versus open bogs.

In some instances demands were put on the data which could not be met. For example, land cover is often of such diversity that absolute discrimination of type cannot be obtained from satellite data or perhaps even with aerial photography. A mixed forest is exactly that and complete separation of deciduous and conifers may not be possible even though it may be desirable. As a result expectations and criteria sometimes had to be lowered. Problems of this nature however, were resolved by the principal investigators and the results which they obtained were acceptable. Calculations of the area of cover types, once acceptable criteria were established, were always made with a speed and accuracy that far surpassed any other available method of area determination.

The study of saline areas was particularly challenging. Where accuracies of classification for the crop and summer fallow study were 75% and better, accuracies of classification of saline soils fell between 20% to 30%. Nonsaline soils were misclassed, not through mishandling of the data by the resource manager, but because the differences in spectral reflectances of the soil types were too subtle to separate. This did not mean that the project was a failure. Rather it indicates that a different type of data (such as from radar) may be required, or that the digital data must be visually interpreted, or that a more appropriate biological window needs to be identified.

The study of artificially drained land had a low success evaluation because the criteria for some aspects put demands on the data which could not be met. From the data small ditches and other man-made structures below the resolution of the satellite sensor were to be mapped. The Saskatchewan Water Corporation should not, however abandon satellite imagery as a suitable data source for some of its needs since Landsat or microwave data may well become useful for other hydrological purposes in the future.

There are enormous benefits (Table 2) to be achieved through the use of space-borne data sources for monitoring Saskatchewan's natural resources. The joint projects undertaken within STEP have illustrated many. Most agencies that took part have been able to advance their data collection and analysis procedures, and others have that same opportunity.

2.3.2 Other Projects Undertaken During STEP

The information in this section was derived from eighty replies to a questionnaire sent out to a total of 553 questionnaire recipients. They were received from the following sources:

government agencies	-	39%
training institutions	-	8%
industry	-	25%.

Agro-Tech Systems Inc. has a system under development which uses black and white infrared aerial photography, together with selected soil sampling, to generate a map of fertilizer requirements for a field. The map will be used by the fertilizer applicator to vary the fertilizer application rate according to the actual requirement at each location in the field.

CCRS and Saskatchewan Parks, Recreation & Culture used airborne pushbroom scanner data (and TM data) to detect spruce budworm. Five metre MEIS-II data were successfully used. These data were more accurate than those produced by aerial sketch mapping. SPR&C has used aerial IR photography for its regular forest inventory assessment although it was curtailed due to weather this year.

Ducks Unlimited produced a wet lands inventory of NTS map sheet 73A at a scale of 1:50,000 using TM data. The imagery was analyzed using an unsupervised classification procedure.

King and Associates, Regina, undertook a FAO contract for the All India Soil and Land Use Survey. This contract involved preparation of a Geographic Information System for Landsat data. A World Bank sponsored study involving the use of Landsat data as a base map for a land resource in Somalia was carried out by the same firm.

The National Hydrology Research Institute (newly established in Saskatoon) is looking at the use of NOAA and Nimbus satellites for snow melt studies, in particular the gradient from moist to dry ground.

The Saskatchewan Institute of Pedology used black and white aerial photography for soil survey, salinity, soil fertility, and delineating soil associations and infra-red photography as part of the Innovative Acres Program for salinity assessment.

J.D. Mollard & Associates, Regina, used airborne imagery for lakeshore studies and shoreline engineering relating to recreation development and water level optimization. This company has used satellite data for petroleum exploration and exploitation in Saskatchewan. In addition, remote sensing was used in the routing study of a transmission line between Uranium City and Wollaston Lake. Slope features were assessed using remote sensing to evaluate the effect of gas line construction on valley and hill sides. The search for sand and gravel deposits, locating and evaluating new dams/water storage reservoirs for irrigation and International water releases, rout selection, peat engineering, and oil and gas exploration (salinity, waste disposal, and groundwater management) were also studied using satellite imagery.

George Mueller & Associates were contracted to collect ground data in Flett Springs RM, including crop identification for CCRS.

Saskatchewan Agriculture (Irrigation Branch now part of Saskatchewan Water Corporation) utilized false colour imagery in the Outlook area for planning and follow-up of salinity reclamation on irrigated land.

Saskatchewan Mining and Development Corp. (SMDC) has been involved in the following projects: research into the methods of regional geological structures in Northern Saskatchewan; terrain classification studies used to complement environmental impact assessments

for mineral development projects; and research into methods of analysis of regional geophysical data (eg. airborne magnetic data) through image processing.

Saskatchewan Parks Recreation and Culture undertook a study using Landsat transparencies to map native vegetation habitats which were greater than 80 acres in south-eastern Saskatchewan for the white-tailed deer habitat acquisition program. Forest Fire Control (SPRC) is co-operating with SED Systems, CCRS and SRC into the feasibility of using near-real time NOAA data to find forest fire hot spots.

The Saskatchewan Research Council used small scale black and white airborne imagery for biophysical mapping in the Estevan area. Large scale photos were used to identify vegetation types and their aerial extent in the proposed Rafferty Reservoir. A preliminary assessment of oil and gas drilling sites was carried out using aerial mosaics. Soils and vegetation were considered in regard to waste disposal of drilling fluids. The Saskatchewan Research Council has also been active in satellite studies related to geology, agriculture and hydrology. A co-operative project was initiated with France [INREA] on image analysis applied to Integrated Investigation of Mineral Exploration Data. The purpose of this project is the integration of data using raster images in Northern Saskatchewan. The data include bedrock and surficial geology, structure, various geophysical data (ground and airborne), geochemical, topographical, and vegetation. New feature and theme maps were generated, such as magnetic vertical gradient as a variant to economics or terrain.

In another joint project with Saskatchewan Mining and Development Corp. and Mollard & Assoc., structural assessment of the Swift Current petroleum area was made with TM data. Over 2,000 individual lineaments were defined in spite of over 2,000 m of Phanerozoic sedimentary strata overlying the pre-Cambrian basement. Additional assessment was also carried out under contract for petroleum reserves in the Estevan area and for gold in the La Ronge area. The lineament structure in the Athabasca sandstone formation was also assessed to determine whether lineaments caused the dis-jointed drainage pattern. SRC has also been co-operating with Nova Scotia Land Survey College concerning the detection of soil salinity in relation to groundwater discharge. SRC is interested in using the satellite technique to find other such saline areas in the Prairies.

The Saskatchewan Remote Sensing Centre (at SRC) has been involved in a number of small projects in response to problems that have arisen during past projects:

1) **Improved digital burn mapping.** To counteract the problem of classification overflow of new burns into lake reflectances a repeat classification was used. Unsupervised classification of areas having both recent burns and lakes resulted in classification of the burn as well as part of the lake under the same signature file. This could be eliminated by adding signature files developed from lake training areas drawn in the area of confusion and then rerunning the classification using both the unsupervised signature file and the lake signature file developed in the interactive training task. The resulting classification had two separate classes, one for the lakes and the other for the burn.

2) **Enhancement of Thematic Mapper Data.** Principal Component Analysis and Band Ratioing techniques were used to digitally enhance Landsat TM data for the separation of closely related (reflectancly) terrestrial habitats. Native grasslands, crops, and trees and shrubs could be easily separated using standard enhancement techniques available on the Aries II DIPIX system. Visual separation of these habitats was investigated using various combinations of raw channels and enhancement products.

3) **Preliminary results of Biomass Assessment of Forage Crops** using TM and MSS data. Both Principal Component Analysis and Band Ratioing appear to be better than Contrast Stretching for the development of visual products which enhance the separation of biomass levels. It appears that although a product can be developed for the Thematic Mapper, data which delineate different levels of biomass ranging from very low to very

high, more accurate delineation may result if the enhancements concentrate on either the low or high digital values of biomass rather than a single product for the full range of biomass. Low levels of biomass can be emphasized using MSS data if standard band ratio products utilizing ratios of band 7 and 4 and bands 5 and 4 are used in conjunction with raw or enhanced bands 7 and/or 5.

4) **Separation of closely related Habitats** using a two tier classification. Recent work on an arctic site using TM and MSS encountered the problem of separating two cover types; one on a dry site and another on a wet site. Both supervised and unsupervised classification resulted in no or poor separation. The method investigated to resolve this problem was first to classify the area according to the moisture levels and then to classify the area according to vegetation. The signature files resulting from both classifications were then run through the maximum likelihood classifier to separate the dry-confusing habitat from the wet-confusing cover type. TM data were used for this experiment and further work is underway by the University of Regina.

SRC has also used Digital Terrain Models (DTM) to evaluate the snow distribution in a small Prairie watershed, and to use NOAA data for flood runoff prediction using the SSARR runoff model based upon snow cover data. A co-operative program was initiated with the University of Saskatchewan and CCRS to evaluate the use of NOAA data in relating vegetation indices and precipitation distributions to crop yield.

The Saskatchewan Water Corporation uses black and white aerial photography in support of its dam construction and related water supply projects on an on-going bases.

Tamarack Resources has been very active in both airborne and satellite contracts in support of environmental impact assessment, wildlife and agricultural studies.

The University of Saskatchewan was awarded a contract from CCRS to operate the CCRS ground microwave truck last year to collect calibration data. This year was the first complete field season and some 300 tapes of radar return data were collected. Two graduate students are working on these data and a third student has just started analyzing the antenna output. The microwave data will be used to assess the airborne and satellite SAR data. A seminar series was initiated last year with the University of Saskatchewan and continued into this year. Two courses at the University of Saskatchewan use the CCRS/SRC STEP equipment for their lab work.

It is anticipated that the use of remotely sensed data in the province will double during the next year (as it did from 1986 to 1987).

3. THE FOLLOW-ON PROGRAM

The loaned system has been used very successfully and the demand for its use was high. The total time operation was some 8000 hours or 8.3 hours/day (seven days of the week). The STEP computer was also being used outside of business hours (equal to the 9 am to 4 pm time) and on more than 58% of the weekend time available (Table 3).

The time on the system (during the normal business hours) was used as follows: demonstration projects used 42% of the system time, other projects 28%, and training 20% of the time. Over the life of the loan period, including non-business hours, the distribution was 29% Demonstration projects, 28% system time (including teaching, meetings and seminars) and 43% other projects (see Figure 2). Use grew at the rate of 13% per month. In March 1987, the waiting time for system access was 2.5 months, with a cancellation rate of 10%. At any one time, there were 29 users active on the system.

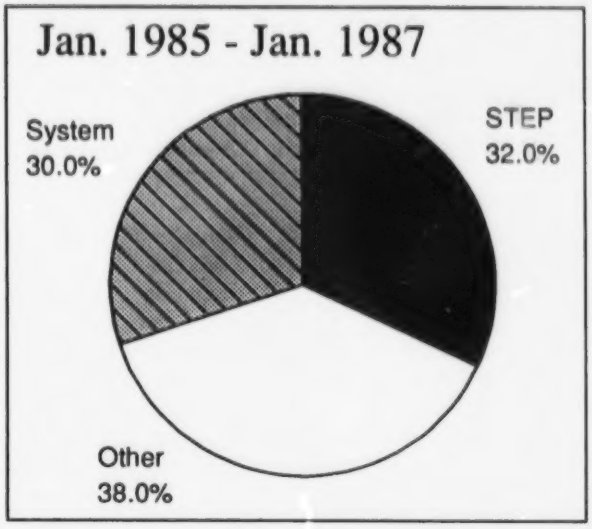

Figure 2. Use of CCRS Digital Equipment.

3.1 Perspective

Remote sensing is a proven technology providing a cost effective tool for the monitoring and managing of resources. Significant potential benefits for the management of Saskatchewan's vital and diverse resources have been demonstrated and a commercially viable, follow-on program has been designed to provide the desired services. While other provincial centres rely on continued government funding support of between $1 million and $10 million per year, with the proper investment the Saskatchewan facility can be structured to be self-sufficient in three years.

The objectives of a follow-on program in Saskatchewan are:

1. To establish a facility for the near-real time production of resource maps to improve Saskatchewan's resource industry's ability to compete on the international market.
2. To continue training to potential users remote sensing technology.
3. To support the effective implementation of remote sensing technology in Saskatchewan industry.

The SRC operated Saskatchewan Remote Sensing Centre will be a development unit which will work with both small and medium sized service companies and large resource companies to develop remote sensing applications (products) to serve the needs of the resource sector. As the products are developed, tested and demonstrated, they will open up markets for the small and medium sized service companies.

3.2 The Need

In recent years, Canadian resource industry competitiveness in international markets has

TABLE 3.
SYSTEM USE (IN HOURS) FOR 1985-87 - ending Sept. 30, 1987

Principal Investigator	Subject	1985 Yr. Total	1986 Yr. Total	1987 Yr. Total	Project Total
A. STEP DEMONSTRATION					
1. P.Beaulieu	Deer Habitat	125	116	0	241
2. S.Benjamin	Crop Insurance	62	114	18	194
3. B.King	Soil Salinity	110	18	0	128
4. M. Campbell	Forestry-Fire	146	113	0	259
5. J. Polson	Moose Habitat	324.5	115	0	439.5
6. J. Polson	Caribou Habitat	5	145	0	150
7. D.Ens / B.Reid	For. Inventory	66	185	6	257
8. A.Didiuk	Wetlands		151	0	151
9. B.Kallenbach	Flooded Land		162	0	162
B. OTHER USERS					
10 Polson/Bashak	Rangeland	94	0	478.5	572.5
11. B.McCall	Land Use	88	0	0	88
12. L.Seileki	Land Use	131	81	0	212
13. J. Whiting	agri. & geology	106	157	139	402
14. M.Mellinger	Geology Appl.	72	202	39	313
15. H.Epp	Meis-TM Appl.	37	225	188	450
16. K.Kedves	Oil Explor	28	0	40	68
17. A.Didiuk	For. Appl.	5	312	249	566
18. G.Adams	Wetlands	14	0	0	14
19. W.Liaw	Fisheries	3	0	0	3
20. P.Mason	Morphology	0	47	0	47
21. S.Earl	SMDC-Geology	0	214	79	293
22. Others		0	277	427	704
C. System					
23. System	agri+NOAA	138.5	371	407	916.5
24. Seminars	seminars	21	43	0	64
25. Meeting	meeting	12	140	4	156
26. Demonstration	demos	81	65	17	163
27. Training	training	279	239.5	67	585.5
28. Down	dowm	234	72	52	358
	TOTAL HOURS IN USE	2182	3564.5	2210.5	7957
	% WEEKEND IN USE	46	76	60	61
	% WORKING DAY IN USE	124	254	233	204

been under considerable pressure. This situation has worsened due to significant reduction in world prices for Canadian resources, which has contributed to unemployment and underemployment, inflation and erosion of living standards. One challenge, as seen by the Federal Ministry of State for Science and Technology, is to promote the ability of Canadian resource companies to develop and adopt new technologies as a means of increasing productivity.

Canada's rich endowment of natural resources and its considerable expertise in developing these resources provide a solid base from which to build. The role that natural resources play in the Canadian economy is significant in all regions of Canada and a major contributor to our trade balance. In the present economic climate, development and adoption of new technologies has the potential of increasing productivity within resource industries, thereby improving Canada's competitive position.

By 1990, the world market in remote sensing is expected to be $2 billion (US) and $10-15 billion by 2000. Expenditures by the Canadian government for remote sensing totalled $74 million last year; this represents 38% of the total space budget and is the largest single portion. Canada has recognized the importance of remote sensing and invested in it. Canadian industry has responded to the opportunity and achieved world status as well as significant sales.

There are numerous studies which demonstrate the benefits of using remote sensing in real dollar terms. Estimates from United States and Canadian sources suggest that typical benefits range from 20 to 70 times the total investment in remote sensing. In other words, a $1 million investment will typically provide $20 to $70 million in benefits. This return, however, may take 5 to 15 years depending upon the rate of acceptance by the various user agencies in the public and private sectors.

SRC is poised on the threshold of the future: working with industry to see that resources are readily available and are developed for the benefit of Canadians. The Saskatchewan Remote Sensing Centre will also ensure the continued contribution towards the national integration of remote sensing activities and will expand the links to industry.

APPENDIX
WHAT IS REMOTE SENSING

Remote sensing is the ability to measure the characteristics of a material from a distance; in this context, it is the observation of the earth's resources from space. All types of ground cover, from rocks to vegetation, absorb some wavelengths of light and reflect others. Remote sensing satellites monitor these wavelengths reflected from the earth and radiated by objects on the earth. The data, when processed and analyzed, can help locate minerals and petroleum, inventory crops and forests, discern the health of natural and cultivated vegetation, and even identify the stresses of drought, disease and insect infestation, and human intervention. The view from space allows repetitious monitoring of all areas, regardless of how inaccessible they may be. Thus, remote sensing can vastly improve management of resources such as agriculture and forestry. It is becoming increasingly important to the mining and petroleum industries. The capacity to monitor resources in this way is especially suited to Saskatchewan because of our geography and demography and because of our resource-based economy.

Remote sensing, while not a new technology in itself, is new to most resource managers. It is a substantially different method and before it can be implemented, the user must change his department's methods, management approach and labour utilization. At the present, it also requires the user to acquire new equipment and skills. While the variety, utility and costs of suitable processing equipment have been steadily improving, capital outlay for a practical system is still significant. There are the additional costs associated with the training of personnel in remote sensing techniques. The training invariably illustrates another type of overhead, that of learningnumerous computing terms and methods not directly or obviously associated with resource management.

This cost overhead may present a barrier to the operational use of satellite remote sensing. Only those resource managers who anticipate volume requirements are likely to opt for their own systems while potential users, whose demands are lower are often forced to abandon the idea completely. For them, the unique advantages offered by remote sensing are not sufficient to justify conversion. The need exists to bridge the gap between remote sensing and resource management, making it more accessible.

The provincial centres, while very successful in training and educating potential users, tend to stop short of operational and on-going support. An initiated client, when eventually faced with the economic and managerial decision of committing to the on-going use of remote sensing is still confronted by the overhead factors of purchasing his own system and training additional personnel. Again, only managers anticipating volume requirements will opt for this choice, leaving the lesser users without access to remote sensing and its benefits.

A better solution is possible through a centre designed from the outset to address the needs of all potential users. The facility must not only introduce the technology but also continue to provide a variety of services and products to make it accessible to the entire spectrum of users. Those who opt for their own systems must be supplied with input data in a suitable format. The users of Geographic Information Systems are a prime example of this need. Others may opt to purchase the information products directly instead of producing them themselves,eliminating the need for purchasing their own systems and re-training their personnel.